

Influence of Fire on Mercury Cycling in Boreal Forests

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Team Leader & Research Soil Scientist



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Research Forum
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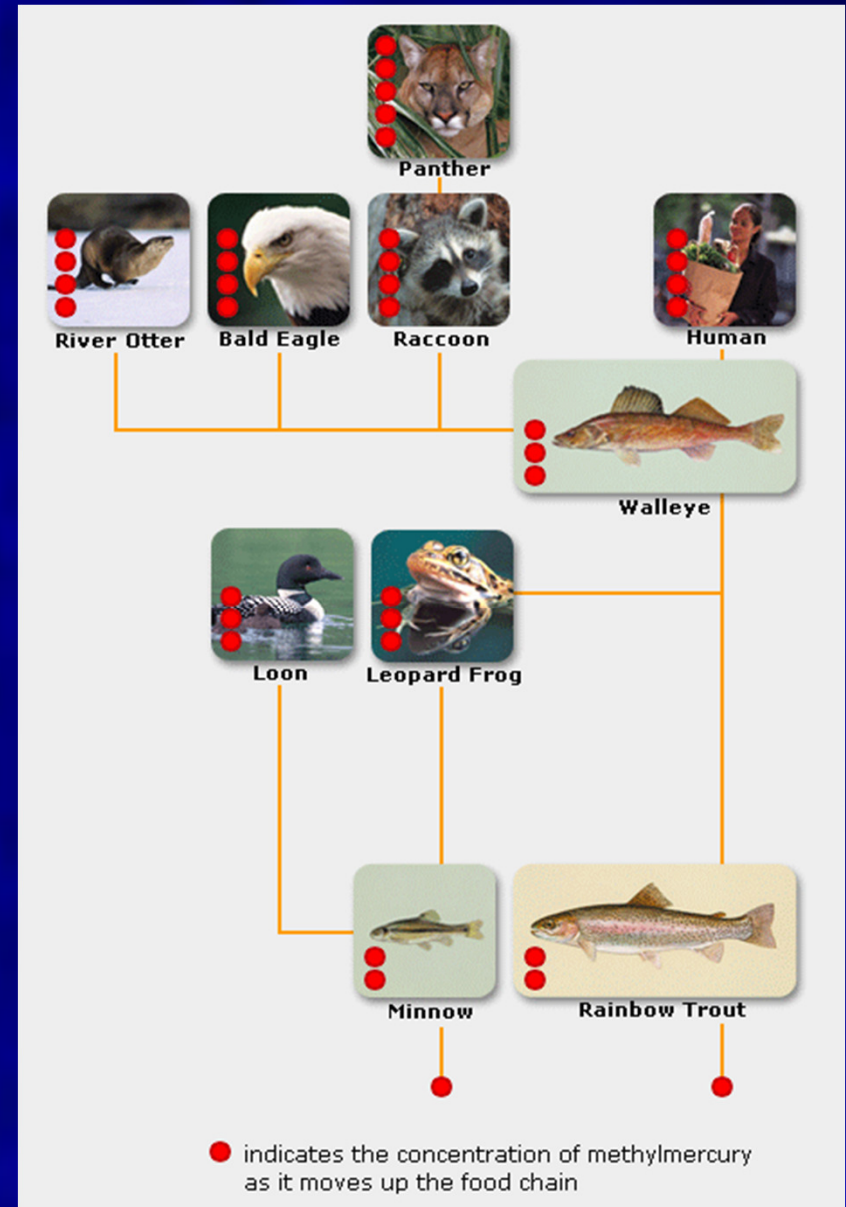


Outline

- **Background on Hg**
 - **Health Risks**
 - **Sources and Forms of Hg**
 - **Landscape Influences**
- **Fire Effects on Mercury Cycling**
 - **Fire Effects on Mercury Deposition**
 - **Fire Effects on Soil Mercury**
 - **Relationships between Forest Floor and Fish Mercury**
- **Summary**

Background – Health Risks

- **Bioaccumulation in the Aquatic Food Chain**
 - **BAFs of ~ 1 million in Humans**
 - **New Research – Terrestrial Bioaccumulation? Not really!**

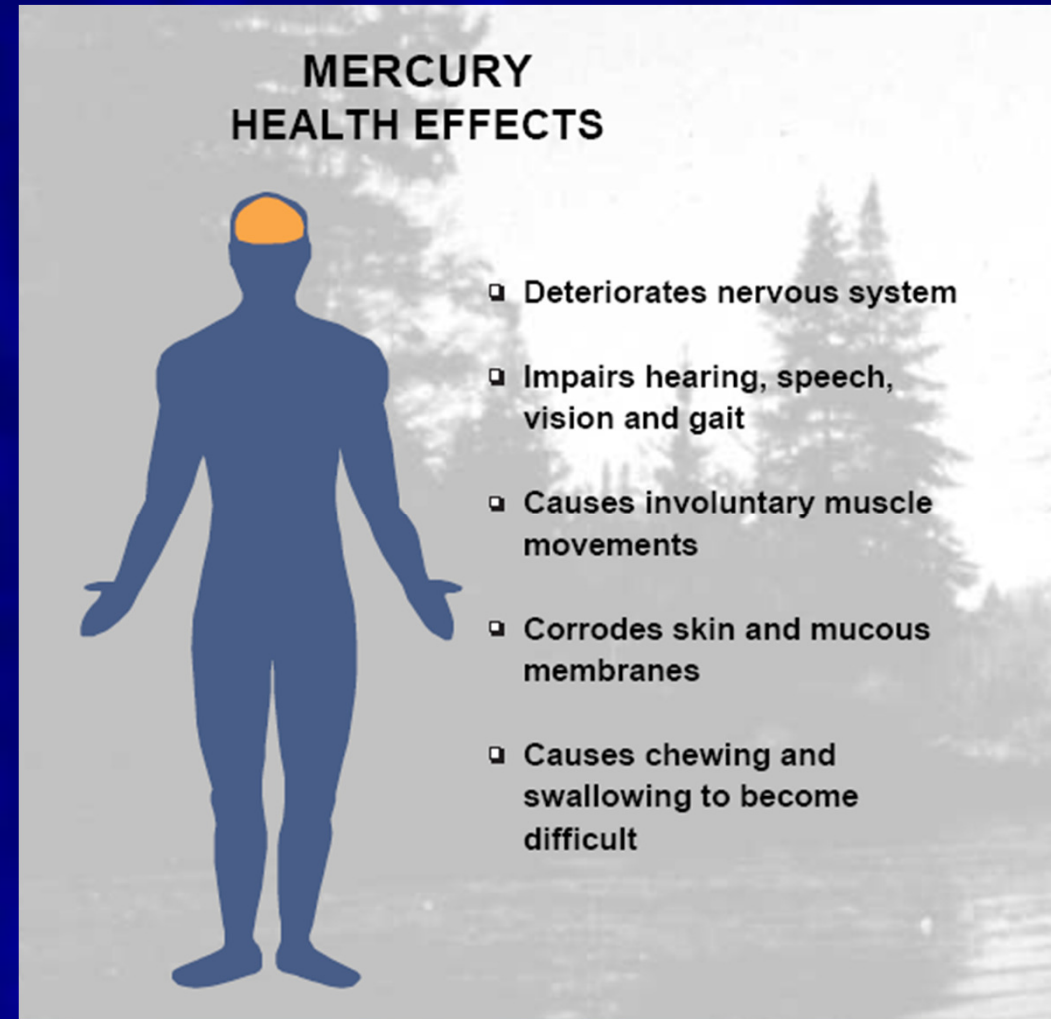


Background – Health Risks

• Health Consequences

- **Attacks Neural Network and Nervous System**
- **Reproductive System**
- **Mercury Poisoning**
 - **Mad Hatters Disease**
 - **Iraq Poisoning**
 - **Minamata Disease**

Not until the mid-1950's did people begin to notice a "strange disease". Victims were diagnosed as having a degeneration of their nervous systems. Numbness occurred in their limbs and lips. Their speech became slurred, and their vision constricted. Some people had serious brain damage, while others lapsed into unconsciousness or suffered from involuntary movements. Furthermore, some victims were thought to be crazy when they began to uncontrollably shout. People thought the cats were going insane when they witnessed "suicides" by the cats. Finally, birds were strangely dropping from the sky.



Background – Health Risks

- **Susceptible Groups**
 - **Fetuses and Young Children**
 - **Women of Childbearing Age**
 - **Native Americans, Asians and Pacific Islanders**

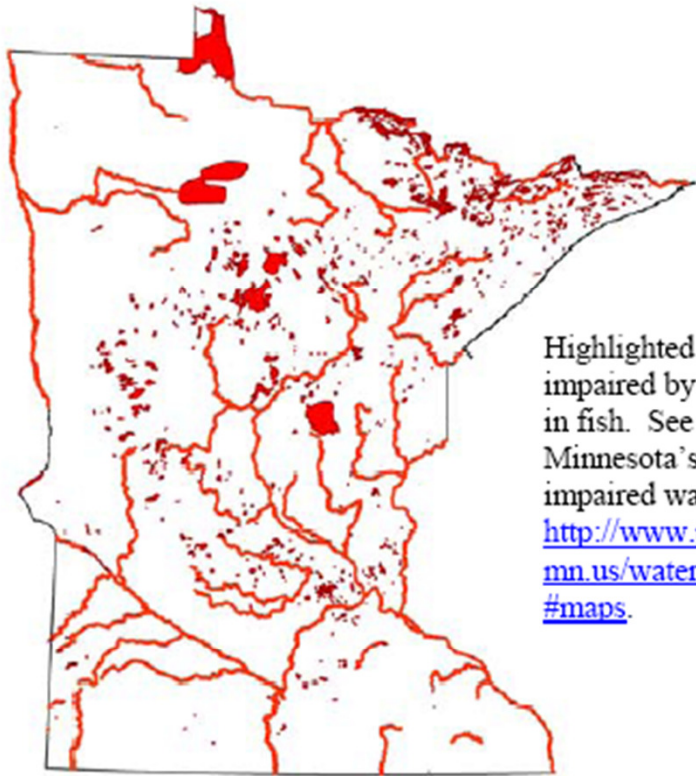


Background – Health Risks

- **Fish Consumption Advisories**
 - **Now in Every US state, Canadian Province and Across Europe**
 - **In MN All Surface Waters Have Warnings**



Background – Health Risks



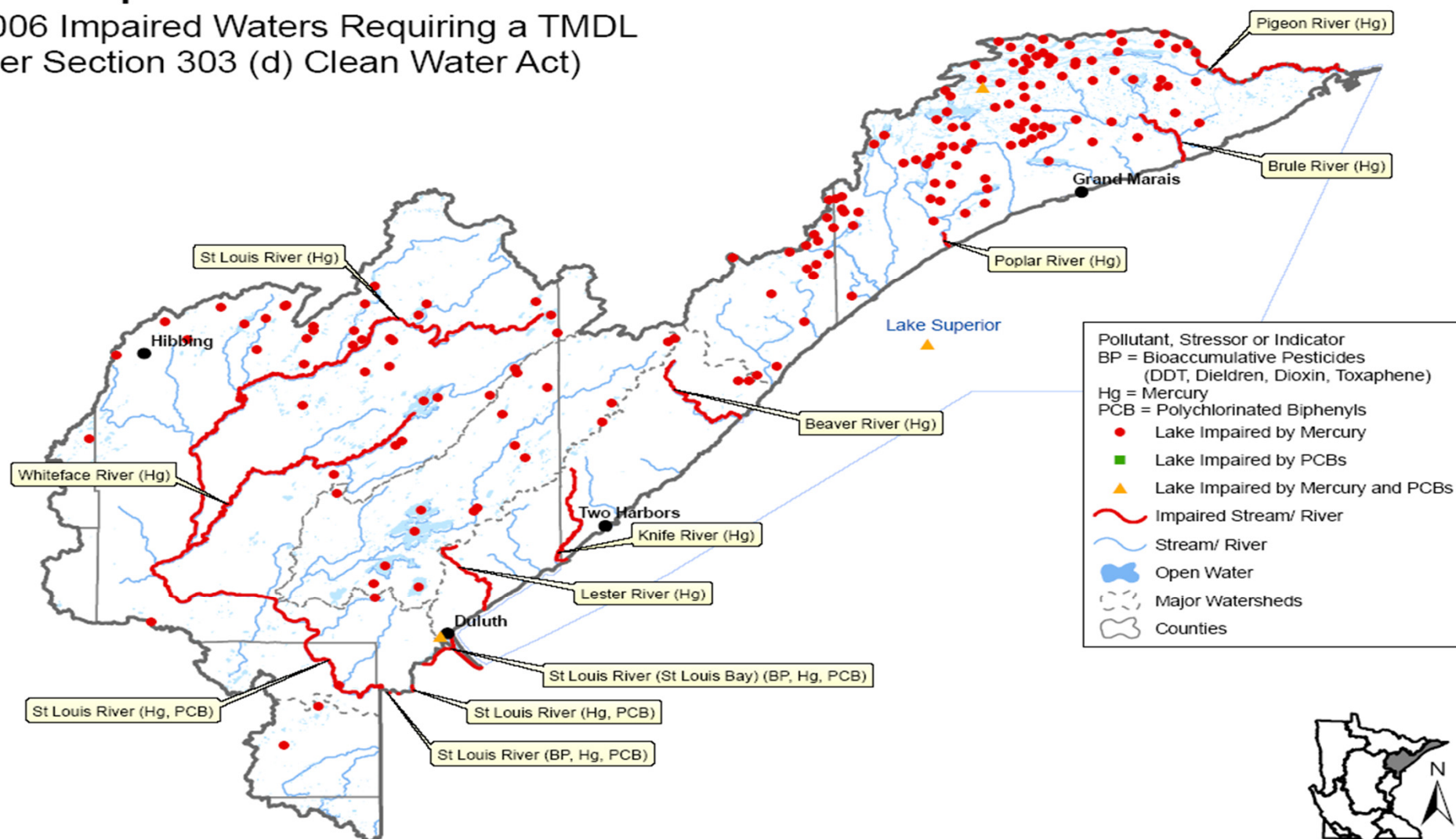
Highlighted waters are impaired by mercury in fish. See maps of Minnesota's mercury-impaired waters at <http://www.pca.state.mn.us/water/tmdl.html#maps>.



Background – Health Risks (e.g.)

Lake Superior Basin: Bioaccumulative Toxics

2006 Impaired Waters Requiring a TMDL
(per Section 303 (d) Clean Water Act)



For additional information concerning impairments, such as station information and monitoring data, see the MPCA Environmental Data Access System. <http://www.pca.state.mn.us/data/edaWater>

0 5 10 20 30 40 Miles

Background – Health Risks

Pregnant Women, Women who may become pregnant and Children under age 15

RIVER NAME	Species	Meal Advice				Contaminants
		Unrestricted	1 meal/week	1 meal/ month	Do not eat	
St. Louis Fond du Lac Dam to Lake Superior	Crappie, Sunfish		All sizes			Mercury
	Perch		All sizes			Mercury
	Northern Pike			All sizes		Mercury
	Walleye			Shorter than 20 inches	Longer than 20 inches	Mercury & PCBs
	Smallmouth Bass, Catfish			All sizes		Mercury & PCBs

Background – Health Risks

General Population

RIVER NAME	Species	Meal Advice				Contaminants
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Background – Health Risks

Guidelines for pregnant women, women planning to become pregnant and children under age 15

Kind of fish you eat	How often can you eat it?*
Fish caught in Minnesota:	
Sunfish, crappie, yellow perch, bullheads	→ 1 meal a week
Walleyes shorter than 20 inches, northern pike shorter than 30 inches, smallmouth bass, largemouth bass, channel catfish, flathead catfish, white sucker, drum, burbot, sauger, carp, lake trout, white bass, rock bass, whitefish, other species	→ 1 meal a month
Walleyes longer than 20 inches, northern pike longer than 30 inches, muskellunge	→ Do not eat.
Commercial fish:	
• Shark, swordfish, tile fish, king mackerel	→ Do not eat.
• Other commercial species, including canned tuna	→ See MDH's brochure, "An Expectant Mother's Guide to Eating Minnesota Fish."

* These guidelines apply even if eating fish just during a vacation or for just one season.

Background – Health Risks

Guidelines for men, and for women not planning to become pregnant

Kind of fish you eat

How often can you eat it?*

Fish caught in Minnesota:

Sunfish, crappie, yellow perch, bullheads

→ unlimited amount

Walleyes, northern pike, smallmouth bass, largemouth bass,
channel catfish, flathead catfish, white sucker, drum,
burbot, sauger, carp, lake trout, white bass, rock bass,
whitefish, other species

→ 1 meal a week

Commercial fish:

Limit the following species: shark, swordfish,
tile fish, king mackerel

→ 1 meal a month

* In general, adults who eat fish just during vacation or one season can eat fish twice as often as recommended in these guidelines.

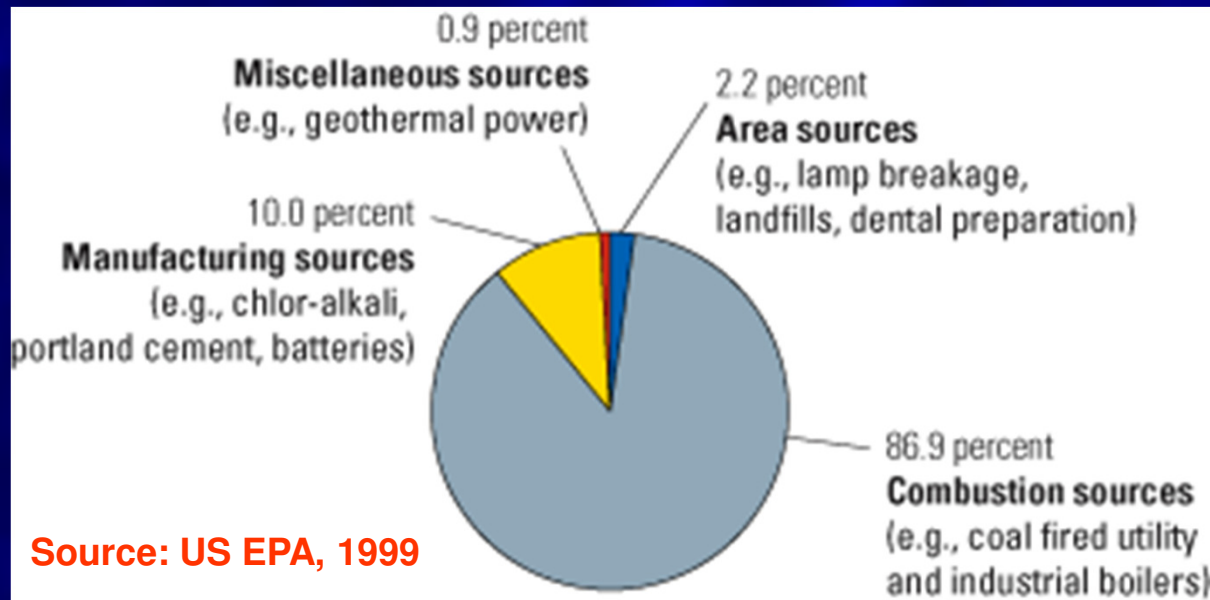
Background – Sources of Hg

- Natural Sources of Hg
 - Not Many
 - Geologic Materials
 - Cinnebar
 - Volcanic
 - Carbon Deposits

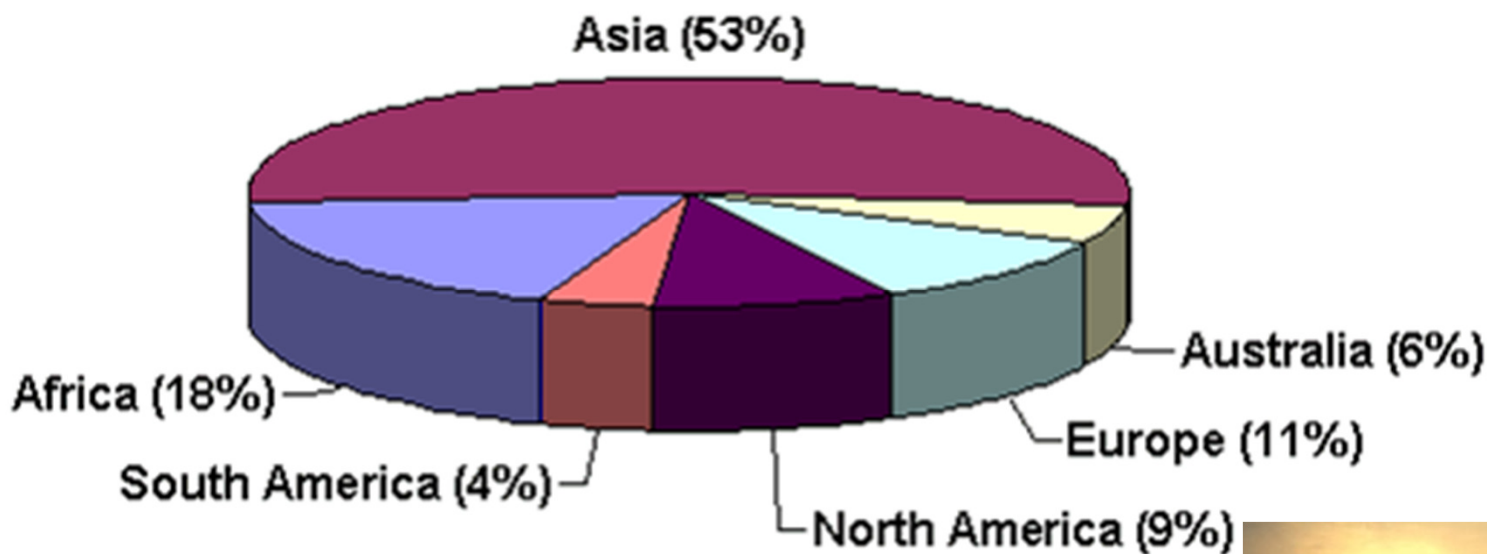


Background – Sources of Hg

- **Anthropogenic Sources of Hg**
 - **Power Plants**
 - **Other Fossil Fuel Combustion**
 - **Manufacturing**



Background – Global Geographic Sources of Hg



Pacyna and Munthe, 2004



Beijing, 2006

Background – Sources & Forms of Hg

- Atmospherically Derived

- Precipitation + Dry Deposition
- Local to Global Sources

- Important Forms

- Gaseous (Elemental)
- Ionic
- Organic - Methyl Hg
(HARMFUL!)

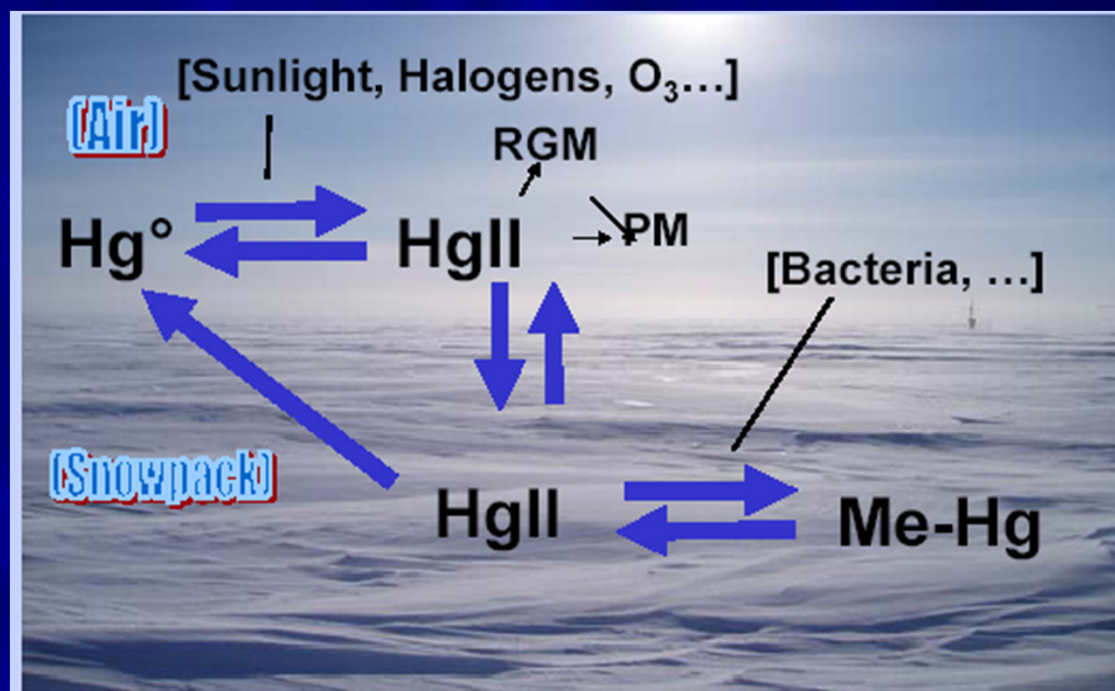
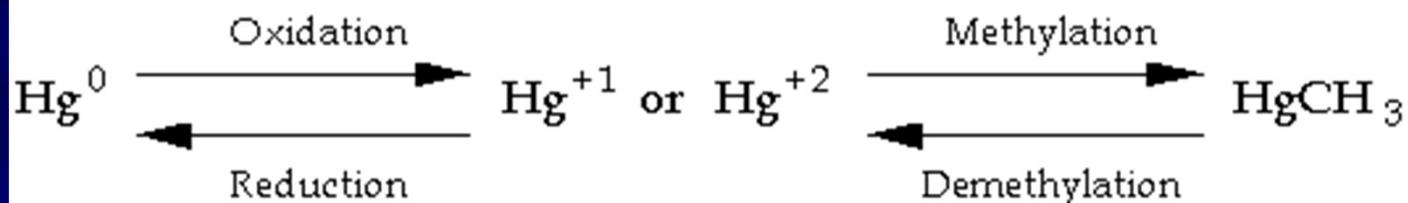


Figure 2-1
Common Mercury Transformations



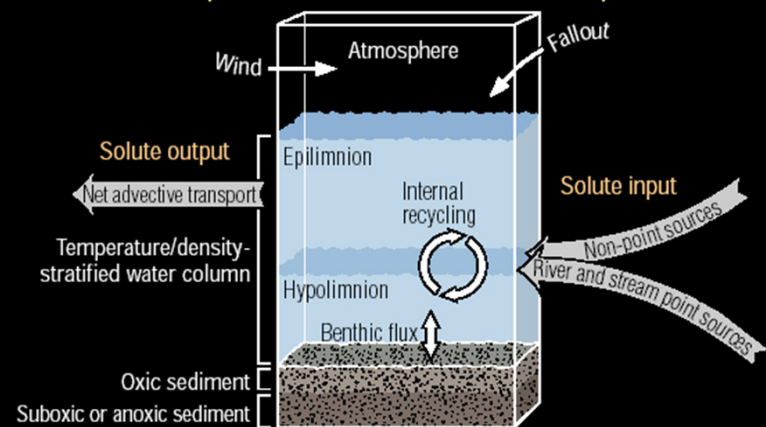
Background – Landscape Influences

- Production of Methyl-Hg
 - Low Oxygen
 - Food (Carbon)
- WETLANDS
- LAKE/STREAM BOTTOM



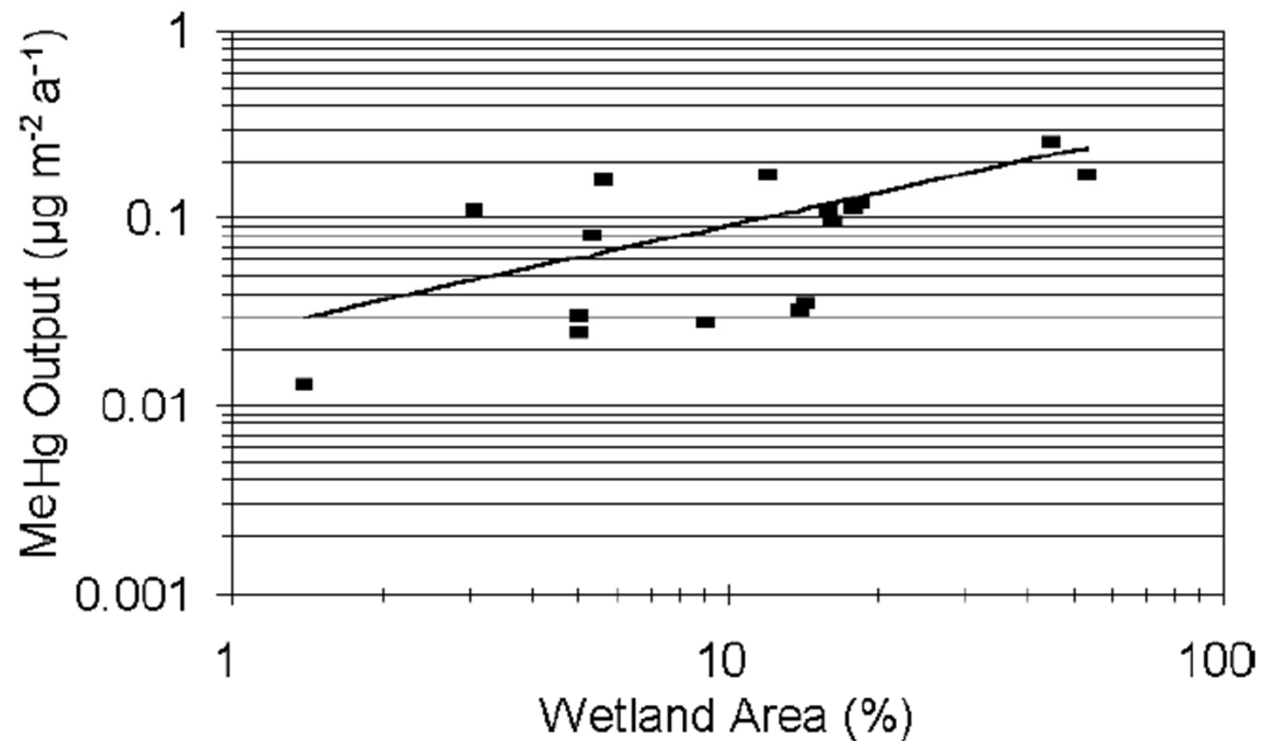
Fig. 6

Conceptual Model of Solute Transport



Background – Landscape Influences

- WETLANDS



Grigal et al., 2002

Fire Effects on Mercury Cycling

- Fire Effects on Mercury Deposition
- Fire Effects on Soil Mercury
- Relationship Between Forest Floor and Fish Mercury



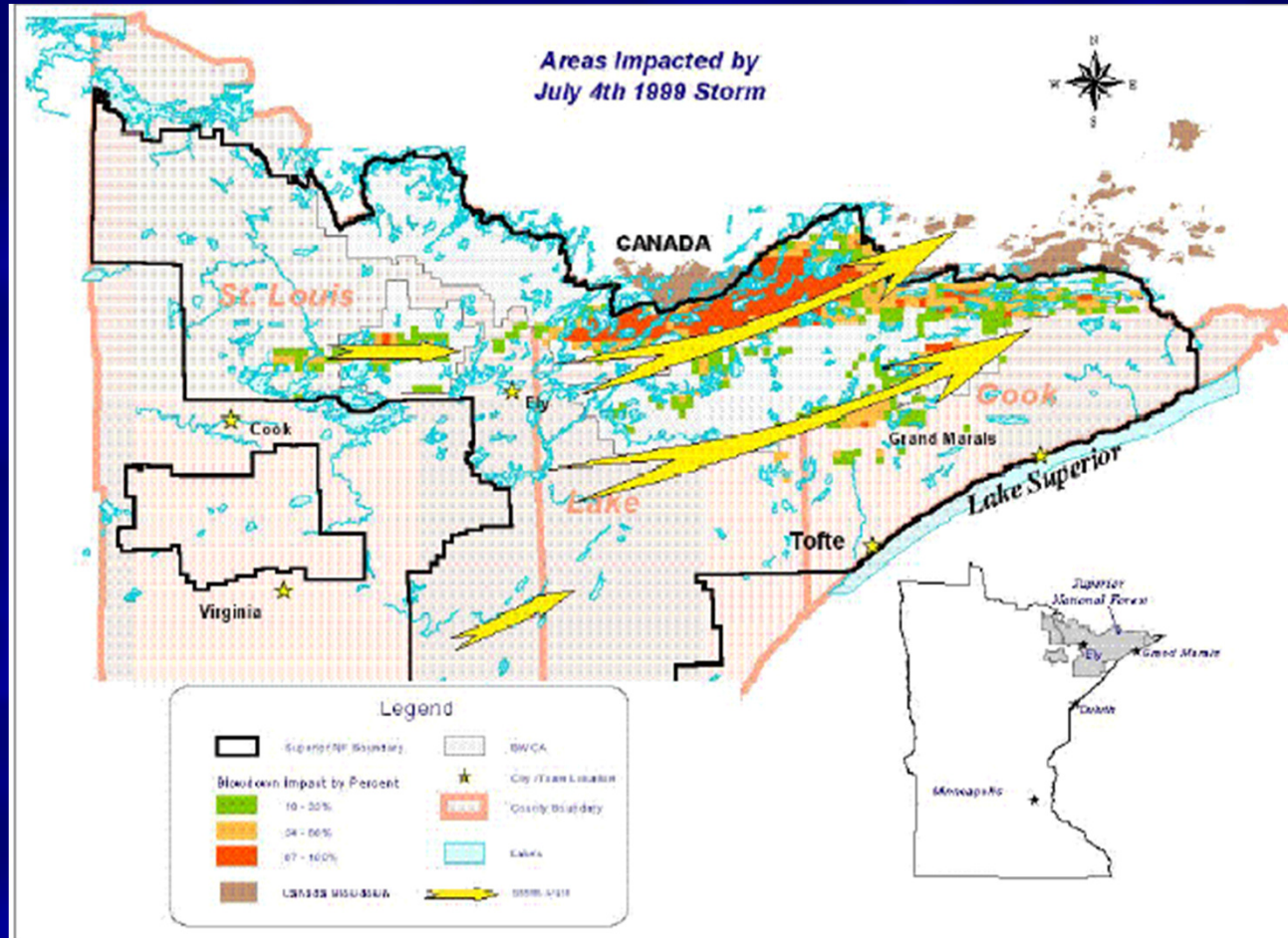
Fire Effects on Hg Cycling

- **Hypothesis:** Burning leads to greater Hg deposition and subsequent short-term elevated Hg in fish



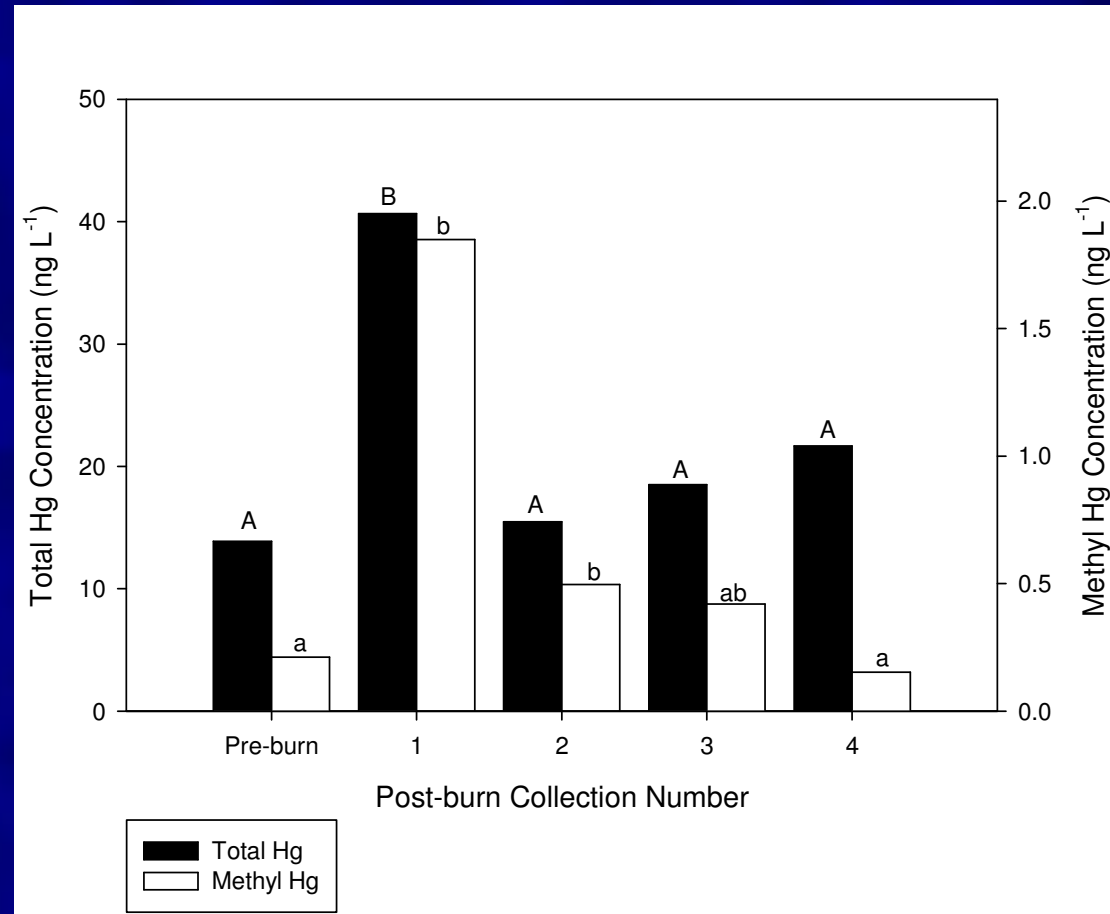
Fire Effects on Hg Cycling

- Blowdown in BWCA of the Superior NF
- ~200,000 ha
- Five control and five burned watersheds
- Also had two wildfires during the study (Alpine and Cavity Lake)
- Measuring Hg in soil, precipitation, throughfall, lake water and fish



Fire Effects on Hg Deposition

- Fire leads to higher short-term deposition of Hg (both Total and Methyl), especially in conifer systems
- Increase is about 30-40% of annual deposition
- Can we pick up that pulse of Hg in the food chain?

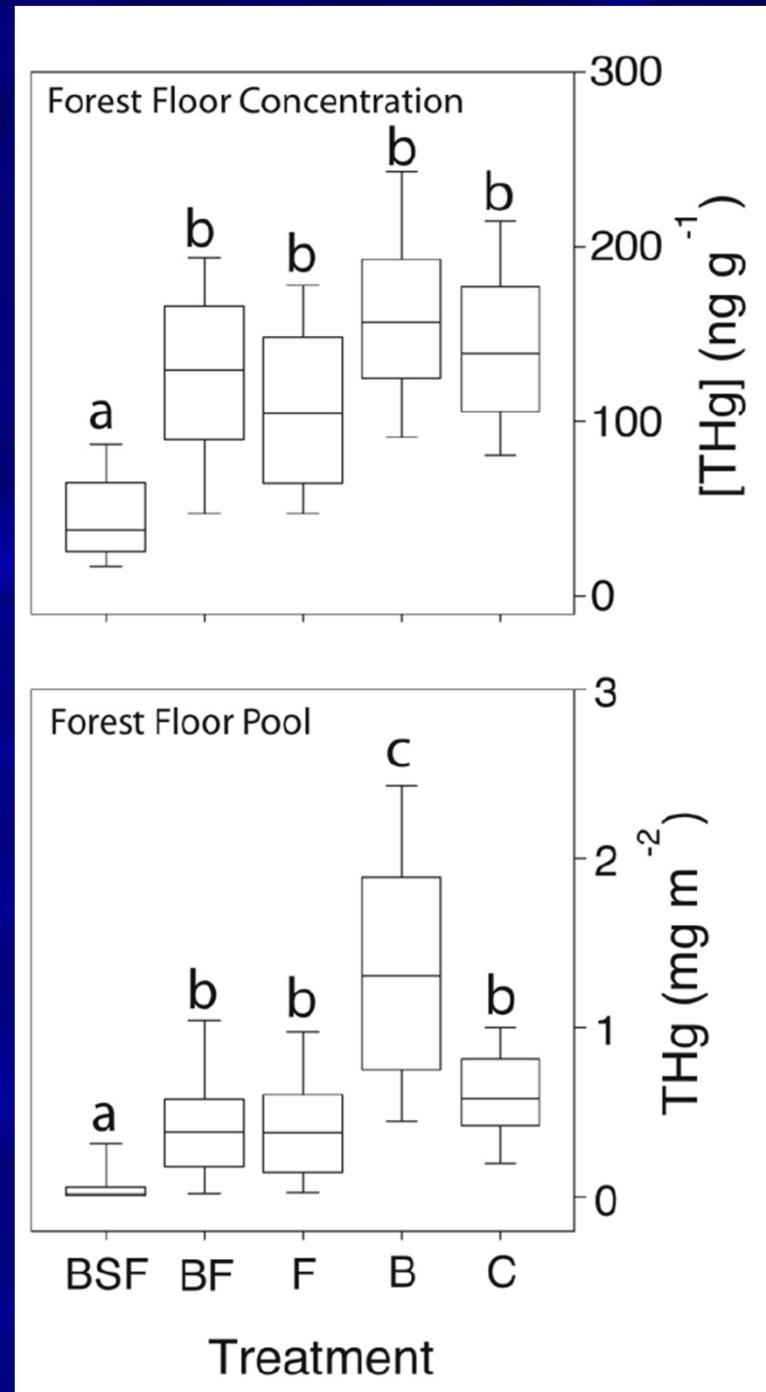


Witt et al., 2009b

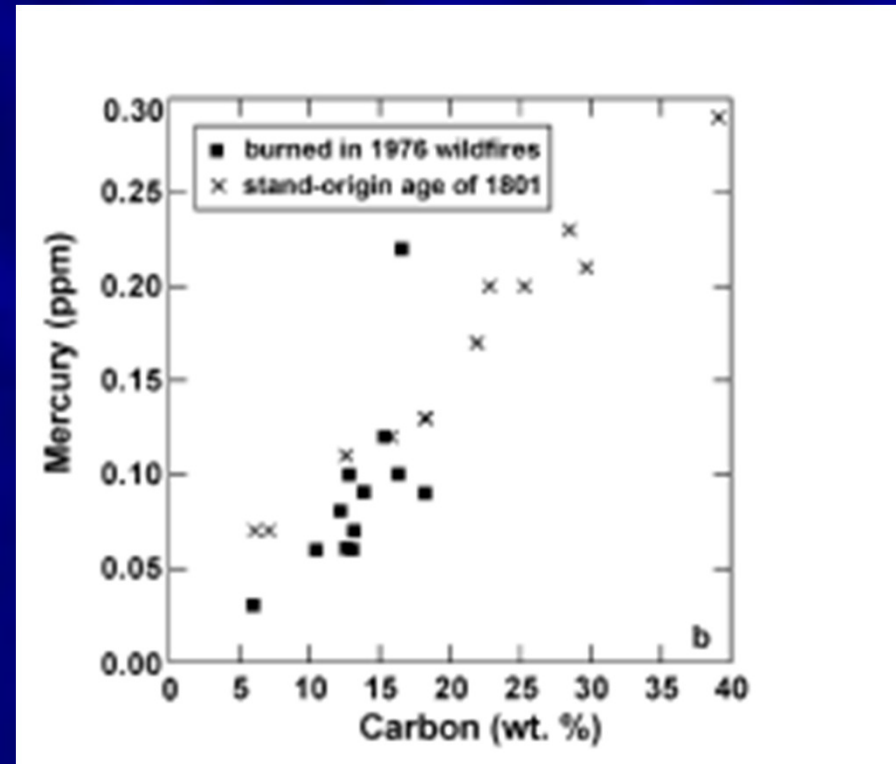
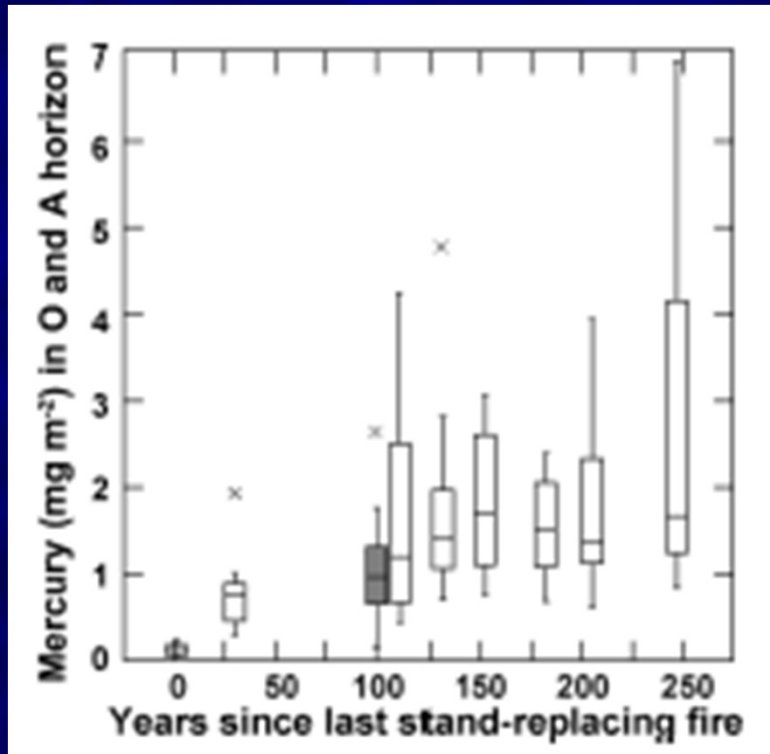
Fire Effects on Soil Hg (Short-term)

- **Forest Floor**
 - Areas with blowdown followed by salvage logging and then fire has lower Hg in forest floor
 - Here fire alone did not change Hg in forest floor (unlike most other studies)
- **Mineral Soils**
 - No differences

B = Blowdown, S = Salvage Logging, F = Fire, C = Control, (Mitchell et al. 2012)



Fire Effects on Soil Hg (Long-term)



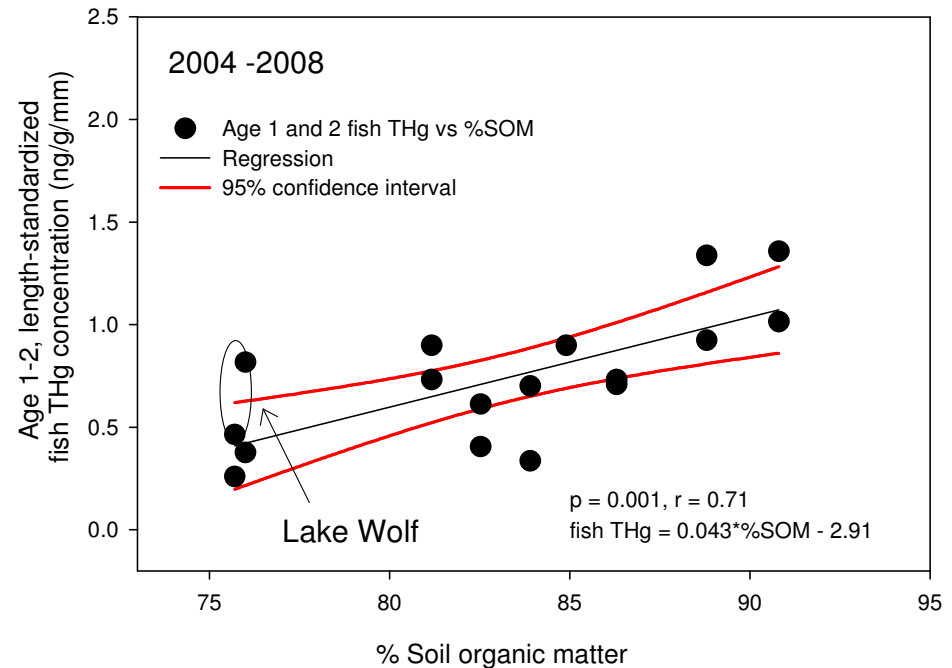
- Soil Hg lower in areas more recently burned
- Close relationship between %C and Hg

(Woodruff et al. 2010)

Relationship Between Forest Floor Hg and Fish Hg

As the % organic matter (%C) in the forest floor increases fish Hg increases

(Gabriel et al. 2012)



- Fire decreases Hg in forest floor and possibly A horizons
- Relationship between watershed soil OM and fish Hg
- Increased deposition the year following fire, but then lower Hg soils
- Perhaps a blip in fish Hg following fire but then probably long-term decreases because the watershed pool is smaller

Summary – Fire Effects on Hg Cycling

- Fire leads to increased Hg deposition in downwind areas following fire.
- Deposition can be ~30-40% of annual deposition.
- Possibly then, fire could lead to short-term Hg increases in fish.
- Fire lowers Hg in watershed soils.
- Positive relationship between watershed soil Hg and fish Hg.
- Theoretically then, fire should lead to long-term decreases in fish Hg – Still working on it...
- Possible management recommendations include imposing a short-term 2-5 year consumption advisory on lakes affected by fire.
- Following fire, good to mitigate soil erosion. Mercury is closely associated with carbon, so keeping O and A horizon material out surface water bodies is important.

Thank You!



Questions?